Florida Power & Light Company, 6501 South Ocean Drive, Jensen Beach, FL 34957

FPL

October 22, 2002

L-2002-212
10 CFR 50.12
10 CFR 50.4

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

Re: St. Lucie Unit 1
Docket No. 50-335
FPL Response to Request for Additional Information for
10 CFR 50 Appendix R K1 Exemption Clarification/Request

The March 5, 1987 NRC safety evaluation report (SER) for the St. Lucie fire protection features states that 25 feet of vertical separation exists between raceways containing redundant divisions of safe shutdown cables in the Unit 1 containment. The statement in the SER does not match the actual plant condition. On October 4, 2000, via FPL letter L-2000-164, Florida Power & Light (FPL) resubmitted exemption K1 to correct the discrepancy identified in the NRC SER for the St. Lucie Unit 1 containment building regarding vertical separation criteria. Following discussions with the NRC staff, FPL supplemented that submittal with a risk-informed evaluation of exemption K1 via FPL letter L-2001-153, dated June 28, 2001. Discussions with the NRC staff led to the abandonment of a risk-informed approach, and both FPL and the NRC agreed to a deterministic fire model approach.

NRC staff requests for additional information were submitted via NRC letters "Request for Additional Information Regarding the 10 CFR Part 50, Appendix R, Exemption Request K1 for the St. Lucie Plant, Unit 1 (TAC No. MB0300)," dated August 31, 2001 and March 5, 2002. FPL provided responses via FPL letters L-2001-267, dated November 29, 2001, and L-2002-070, dated May 15, 2002. FPL and the NRC staff discussed additional clarifications on the May 2002 submittal and the NRC staff transmitted the formal request for additional information via NRC letter dated October 4, 2002. This letter provides the FPL response to the October 2002 NRC RAI.

Please contact us if there are any questions regarding this submittal.

Very truly yours,

Donald E. Jernigan
Vice President
St. Lucie Plant

DEJ/KWF

Attachment 1 - FPL Response to NRC RAI Dated October 4, 2002..............................11 Pages

A006

FPL Response to NRC RAI Dated October 4, 2002

This RAI response refers back to information previously submitted by FPL letter L-2002-070. Specifically, when this RAI response refers to the "Hughes Report," reference is made back to Attachment 2 (Fire Hazard Assessment of Exposure to Safe Shutdown Raceways at St. Lucie Plant) of FPL letter L-2002-070, dated May 15, 2002.

NRC Question 1:

The staff understands that to reduce uncertainty in the analysis and model conditions conservatively, consideration is routinely given to several factors. How would the model change if the following parameters were applied:

NRC Question 1 (Part A):

Electric Power Research Institute [1991] reports polyethylene/polyvinyl chloride cable heat release rates (HRR) between 312 and 589 kilowatt per meter squared (kW/m^2). The evaluation uses 400 kW/m^2. Use the highest HRR for the maximum expected fire scenario.

FPL Response:

The Maximum Expected Fire Scenario should include conservative but not necessarily limiting values or assumptions. Table 3 of the Hughes Report (Page 31) summarizes nearly 40 individual cone calorimeter tests on cables containing PVC and only seven were found to exceed a unit heat release rate of 400-kW/m^2. Only five of these seven were significantly (i.e., over 100-kW/m^2) greater than 400-kW/m^2. Furthermore, six of the seven were peak heat flux values; the average heat release rate is used in the analysis and is much lower, perhaps half as much [see Braun's data, Tables 4 and 5 on pg. 38 and 39, 1989]. If the peak is twice the average, then only 2 of nearly 40 would exceed 400-kW/m^2, one of which is the 589-kW/m^2 cited above. Because there is a mix of cables in the trays, including different kinds of PVC/PE containing cable, there is no reason to expect that the cables would burn at a heat release rate that is the maximum of all PVC/PE cables tested. A 400-kW/m^2 unit heat release rate is a reasonable MEFS value; the data in Table 3 of the Hughes Report (Page 31) suggests that it is more likely that the cables burn at a heat release rate significantly less than 400-kW/m^2.

None of the cables tested in the calorimeter had a flamemastic coating. The cables in the trays considered are all coated with flamemastic. Future cables will be IEEE 383 qualified. Although the flamemastic coating is not credited in the analysis for reducing the unit heat release rate, it will have this effect. It is therefore not reasonable to select the largest unit heat release rate among a field of 40 for a mix of cable types that are all coated with flamemastic.

Nevertheless, the impact of increasing the unit heat release rate can be determined from the sensitivity analysis summarized in Section 9 of the Hughes Report (Page 52). Specifically, Tables 10e and 11e should be used if the impact of increasing the unit heat release rate to 589-kW/m^2 is sought. The tables show that such an increase, with all other parameters held constant, would be acceptable by a significant margin.

NRC Question 1 (Part B):

The HRR is based on burning surface area. Utilize cable surface area instead of plan width ($W_{P,c}$) for calculating the total heat release rate per meter of cable tray (q'_{tot}), equation 2.

FPL Response:

The analysis itself is internally consistent as far as the use of the cable plan area (or the cable tray width, whichever is smaller). The first of these areas is associated with the cone calorimeter unit heat release rate. Grayson [2000] provides a succinct discussion of the cone calorimeter measurement for cables. Section 12.2.3, in particular (pg. 299), sums this up well:

> "The heat release rate per unit area is obtained from:
>
> $$\dot{q}''(t) = \dot{q}(t) / A_s$$
>
> where A_s is the initially exposed area of the sample, which is the width of the aluminum tray multiplied by 0.0094 m for cable specimens or 0.01 m^2 for material specimens."

Because multiple cable diameters were tested, the "exposed area" in the above equation must be the plan area of the cables tested. Thus, the unit heat release rate measured in the cone calorimeter, a direct input into the model summarized in the Hughes Report, is based on plan area of the cables.

The second area is the correlation of B.T.Lee [1985] that scales small scale and full scale cable tests. He notes the following relation:

$$\dot{q}''_f = 0.45 \cdot \dot{q}''_b$$

which states that the full scale heat release rate is 45% of the cone calorimeter (bench scale) heat release rate. The cone calorimeter heat release rate (q_b) is based on the cable plan area as noted above. The full scale unit heat release rate (q_f) used by Lee to obtain the linear constant is based on the <u>cable tray surface area</u> [compare data points on Figures 4 and 5 on pg. 27 and 28 with the cone calorimeter values listed in Table 1 on pg. 17].

In addition, the heat release rate of the cables is a function of the total exposed surface area of the cable. However, the heat release rate is not constant over the surface of the cable. This is because the pyrolysis rate, from which the heat release rate is derived, is proportional to the net heat flux at the surface. The surface heat flux in turn is strongly dependent on the orientation of the surface. While such a model could be developed, it would be far too complex for this application and there would not necessarily be an increase in accuracy. The approach used in the Hughes Report is based on the plan area of the cable. In essence, the surface specific parameters are normalized by the plan area of the cables and are therefore average values across the cable surface.

The small and large scale test data and the cable flame spread/heat release rate model summarized in the Hughes Report is based on the cable plan width, or the cable tray width, whichever is smaller, not the actual exposed cable surface area. This is appropriate given the data used and analysis performed.

NRC Question 1 (Part C):

Utilize the plan width of the fire ($W_{P,c}$), instead of the cable tray width (W_t) for calculating the fire area in equation 12. Add the area of both ends of the flame ($2*F_h*W_t$) for calculating the emissivity.

FPL Response:

The emitting surface from an array of trays would be the width of a cable tray because lower trays will heat upper trays whether or not they contain enough cables to cover the bottom.

The emissivity could take into account the losses from the edge of the flame in Equation 12 [and Equation 15]. The flame is expected to be triangular, thus the total area should be F_h*W_t. However, including the factor will reduce the net emissivity because the emitting area is increased. Thus, it is proposed to make note that the results are somewhat more conservative because this surface is omitted from the calculation.

The loss term from the bottom of the flame or tray represents the loss term from all of the trays involved taken as the area of a single tray. Even lightly loaded trays will heat the entire area of the tray above.

The impact of the assumption of using a single tray area and including the flame edge losses is given below for a representative case.

Input Parameters

The impact of using the plan width of the cables in lieu of the width of the cable tray and adding the ends of the flame to the emissive power calculation are investigated herein. Three samples from the three-tray array (the Hughes Report Reference Point 2307) and three samples from the four-tray array (the Hughes Report Reference Point 2305) are used as the basis for quantifying the impact of the modified emissive power. The plan width of the cables in the trays is as follows:

Reference Point 2307 (three-tray array):

- M120 (top tray): 0.610-m;
- C120 (middle tray): 0.294-m; and
- L120 (bottom tray): 0.388-m.

Reference Point 2305 (four-tray array):

- M120 (top tray): 0.501-m;
- C100 (upper-middle tray): 0.075-m;
- C101 (lower-middle tray): 0.283-m; and
- L101 (bottom tray): 0.388-m.

The three points selected from each tray use 2 of 3 or 3 of 4 trays with a radiant fraction of 0.4. The flame spread velocity is as calculated using the correlation obtained from the Lee [1985] and Sumitra [1982] data (Equation 5 in the Hughes Report (Page 25)). The emissive powers used for the comparison are defined as follows:

NRC Question 1 (Part C cont'd):

- E_0 - original emissive power (kW/m^2);
- E_1 - emissive power calculated using cable plan area (kW/m^2);
- E_2 - emissive power calculated with loss from edge of flame (kW/m^2); and
- E_3 - emissive power calculated using cable plan area and loss from edge of flame (kW/m^2).

Comparison of E_0 to E_3 illustrates the impact of making both changes requested in Item 1C.

Note: The flame edge loss is calculated assuming that the flame has a triangular profile seen on edge. The base of the triangle is set equal to the plan width of the cables (instead of the cable tray width) to be consistent with the first portion of Item 1C.

Results

The minimum plan width cable tray in the given array is assumed in the first set of calculations. This corresponds to Tray C120 at Reference Point 2307 (0.294-m) and Tray C100 at Reference Point 2305 (0.075-m). Both trays are middle trays. Tables 1 and 2 summarize the results.

Table 1. Emissive Power Corrections at Reference Point 2307 (Three-Tier Array) Using Minimum Cable Plan Width in Array

$\dot{Q}$ (kW)	# trays	E_0 (kW/m^2)	E_1(kW/m^2)	E_2(kW/m^2)	E_3(kW/m^2)	% (E_3/ E_0)
400	2	20.4	22.6	19.4	21.6	+ 5.9
600	2	24.5	26.7	23.7	25.7	+ 4.9
800	2	27.8	30.0	26.9	29.0	+ 4.3

Table 2. Emissive Power Corrections at Reference Point 2305 (Four-Tier Array) Using Minimum Cable Plan Width in Array

$\dot{Q}$ (kW)	# trays	E_0 (kW/m^2)	E_1(kW/m^2)	E_2(kW/m^2)	E_3(kW/m^2)	% (E_3/ E_0)
400	3	20.9	25.2	20.7	24.9	+ 19.1
600	3	25.1	29.1	24.9	28.8	+ 14.7
800	3	28.4	32.9	28.2	32.6	+ 14.8

There are instances where the plan width of the top tray is smaller than 0.075-m, however the entire calculation would have to be performed at the new location because of differences in the cable tray loading, the number of trays, and other parameters.

The plan width of the cable tray that is the actual top tray in the given array is assumed in the second set of calculations. This corresponds to Tray M120 at Reference Point 2307 (0.501-m) and at Reference Point 2305 (0.610-m). Tables 3 and 4 summarize the results.

NRC Question 1 (Part C cont'd):

Table 3. Emissive Power Corrections at Reference Point 2307 (Three-Tier Array) Using Actual Cable Plan Width of Top Tray in Array

$\dot{Q}$ (kW)	# trays	E_0 (kW/m^2)	E_1(kW/m^2)	E_2(kW/m^2)	E_3(kW/m^2)	% (E_3/ E_0)
400	2	20.4	21.0	19.1	19.6	- 3.9
600	2	24.5	25.2	23.2	23.8	- 2.9
800	2	27.8	28.5	26.4	27.0	- 2.9

Table 4. Emissive Power Corrections at Reference Point 2305 (four-tier array) using Actual Cable Plan Width of Top Tray in Array

$\dot{Q}$ (kW)	# trays	E_0 (kW/m^2)	E_1(kW/m^2)	E_2(kW/m^2)	E_3(kW/m^2)	% (E_3/ E_0)
400	3	20.9	20.9	19.5	19.5	- 6.7
600	3	25.1	25.1	23.6	23.6	- 6.0
800	3	28.4	28.4	26.9	26.9	- 5.3

The tables show that there would be a net decrease in the emissive power at the MEFS Reference points identified in the FPL report if Item 1C were incorporated.

The goal of the emissive power calculation is to estimate the radiant energy that is directed toward the target. A case could be made that the correct width to use in the calculation is the total plan width of all cables in the involved tiers. This is because there is a radiant loss term directed vertically upward at each tier that is proportional to the plan width of cables at that tier. Tables 5 and 6 summarize the impact of using this approach. In actuality, this may be somewhat of an overestimate because the radiant loss in this vertical direction would decrease as the base of the tray above was heated; however this would then suggest that using the cable tray width would be the limiting value as time increased to infinity.

Table 5. Emissive Power Corrections at Reference Point 2307 (Three-Tier Array) Using Total Cable Plan Width of All Involved Trays

$\dot{Q}$ (kW)	# trays	E_0 (kW/m^2)	E_1(kW/m^2)	E_2(kW/m^2)[1]	E_3(kW/m^2)[1]	% (E_3/ E_0)
400	2	20.4	18.8	19.1	17.7	-13.2
600	2	24.5	23.0	23.2	21.8	-11.0
800	2	27.8	26.4	26.4	25.1	-9.7

[1]Plan width of top tray used to calculate loss from flame edge

NRC Question 1 (Part C cont'd):

Table 6. Emissive Power Corrections at Reference Point 2305 (Four-Tier Array) Using Total Cable Plan Width of All Involved Trays

$\dot{Q}$ (kW)	# trays	E_0 (kW/m²)	E_1(kW/m²)	E_2(kW/m²)[1]	E_3(kW/m²)[1]	% (E_3/ E_0)
400	3	20.9	19.1	19.5	17.7	-15.3
600	3	25.1	23.3	23.6	21.8	-13.1
800	3	28.4	27.2	26.9	25.5	-10.2

[1]Plan width of top tray used to calculate loss from flame edge

This example calculation shows, for this case, that the use of a single tray area is the loss term and neglecting the flare edge loss effects is conservative.

The use of only a single tray area as part of the loss term, ignoring flame edge losses, the heating of trays by flames below and the results of the calculations given above, demonstrate that the analysis used is conservative.

NRC Question 1 (Part D):

Since the model is not linear, utilizing the critical target heat flux (q'_t) instead of separation distance when calculating the safety factor.

FPL Response:

The safety factor was provided in terms of separation distance as a means of interpreting the results and was included because of prior request by the NRC in Question 1 of the March 5, 2002 RAI. The actual radiative flux versus the critical flux is a more appropriate measure of safety factor. The safety factor is easily cast in terms of the critical target flux (11.4 kW/m²). The safety factor is simply the critical target heat flux divided by the target heat flux, as obtained from Tables 10 and 11. For the MEFS scenarios in the FPL Report, the safety factors are as follows:

- Three tier array: 11.4/3.81 = 2.99
- Four tier array: 11.4/3.77 = 3.02

Note that the safety factor increases when presented in this format.

NRC Question 2:

The Society of Fire Protection Engineers Engineering Guide titled: *Assessing Flame Radiation to External Targets from Pool Fires,* June 1999, recommends a factor of safety of two for well documented radiation correlation and models derived from experimental data. What is the factor of safety if flamemastic on the source fire and the target cable tray is taken into account?

FPL Response:

While the SFPE Engineering Guide recommends a safety factor of two for each of the four radiation models assessed in the guide, not as a general rule, the use of such a safety factor is not necessary for the analysis presented in the Hughes Report. This is because there are

NRC Question 2 (cont'd):

multiple layers of safety factors applied to the assumptions and critical values. In addition, the MEFS results are less than one-half of the critical most conservative target threshold criteria, which means that the safety factor for the MEFS is greater than 2.

The impact of flamemastic on the target is already credited in the threshold heat flux/temperature limits for the cable; thus, there is no impact on the safety factor. The impact of the flamemastic was not credited when developing the exposure fire. The flamemastic will have a decreasing effect on the cable unit heat release rate and the flame spread rate. This in turn would lower the target heat flux. Thus, the flamemastic would represent an increase in the safety factor of the model.

The radiation model does not directly apply a safety factor to the calculated results. However, the minimum safety factor may be estimated by comparing the MEFS target heat flux to the critical heat flux value. This factor is approximately 3, which exceeds the recommended value of 2 in the SFPE engineering guide. There are other safety factors embedded in the model. These include assumptions regarding the location of the emitter and the thermal reaction of the target. The most conservative critical heat flux was used in the FPL analysis. Thermal calculations of individual cable arrays indicate that they could be exposed to higher heat flux levels and still remain below the critical temperature. When these safety factors are quantified, the radiation model can be shown to have an overall safety factor between 3.7 and 7.8. If the unit heat release rate of the MEFS is increased from 400-kW/m^2 to 600-kW/m^2, then the minimum safety factor of the model would decrease to about 1.7. However, as noted above, there are other conservative assumptions in the thermal radiation model that would tend to increase the overall safety factor in this case from 1.7 to the 2.1 to 4.2 range.

The radiation model used in the Hughes Report does not directly apply a safety factor to calculation results. However, the underlying assumptions of the model and the critical values used to define damage have the same effect. The purpose of this discussion is to provide a reasonable estimate of the overall model safety factor under various input assumptions.

a) Base Safety Factor - MEFS Three and Four Tray Arrays in the Hughes Report

The base safety factor is the ratio of the critical target heat flux to the calculated MEFS target heat flux. This is as follows:

- Three tray array: 11.4/3.81 = 2.99
- Four tray array: 11.4/3.77 = 3.02

b) Inherent Model Safety Factors

There are several inherent safety factors in the model. These are as follows:

- The location of the emitting source is assumed at the nearest edge of the burning tray array. This would actually be located in the center of the burning tray array, or 1-ft additional horizontal separation. This reduces the target heat flux by about 19% based on a recalculation of the target heat flux.

NRC Question 2 (cont'd):

- The critical heat flux for the target was developed in the cone calorimeter where losses to the surroundings are significantly less than the tray array configuration. A steady state heat transfer analysis on the surface of a target cable demonstrated that an incident heat flux of 22.5-kW/m^2 is necessary to heat the cable to the failure temperature of 318°C. Note that no credit for this effect is asserted in the analysis (see Section 11 of the Hughes Report (Page 73)).

- A transient evaluation of the fire scenarios indicates that the cables can withstand an exposure to 24-kW/m^2 without exceeding the critical surface temperature.

c) Radiation Model Safety Factors

The safety factors for the one and two tray array are shown in Table 1 beginning with the base case and sequentially including items 1 - 3 above.

Table 1. Summary of Radiation Model Safety Factors

Number of Trays in Array	Base Safety Factor	Safety Factor with:		
		1-ft Increased Separation	22-kW/m^2 Critical Target	24-kW/m^2 Critical Target
3	2.99	3.70	7.14	7.79
4	3.02	3.73	7.19	7.84

d) Base Safety Factor - MEFS Unit Heat Release Rate Increased to 600-kW/m^2

The base safety factor was calculated assuming that the unit heat release rate of the cables were increased from 400-kW/m^2 to 600-kW/m^2. This is as follows:

- Three tray array: 11.4/6.56 = 1.73
- Four tray array: 11.4/6.46 = 1.76

e) Inherent Model Safety Factors

As describe in b) above, the radiation model contains at least three additional safety factors: the location of the source emitter, the critical steady state heat flux, and the critical transient heat flux. The results are summarized in Table 2.

Table 2. Summary of Radiation Model Safety Factors - MEFS Unit Heat Release Rate Increased to 600-kW/m^2

Number of Trays in Array	Base Safety Factor	Safety Factor with:		
		1-ft Increased Separation	22-kW/m^2 Critical Target	24-kW/m^2 Critical Target
3	1.73	2.10	4.10	4.48
4	1.76	2.12	4.06	4.23

NRC Question 2 (cont'd):

f) The impact of flamemastic on the target is already credited in the threshold heat flux/temperature limits for the cable; thus, there is no impact on the safety factor.

The impact of the flamemastic was not credited when developing the exposure fire. The flamemastic will have a decreasing effect on the cable unit heat release rate and the flame spread rate. This in turn would lower the target heat flux. Thus, the flamemastic would represent an increase in the safety factor of the model.

NRC Question 3:

What is the minimum thickness of flamemastic coating needed for the assumption that flamemastic increases the minimum damaging heat flux of Institute of Electronic Electrical Engineers (IEEE) 383 non-rated cable to IEEE-383 rated cable? What is the thickness of the flamemastic coating on the source fire and target cables?

FPL Response:

The assumption is based on test data in which the coating was applied per manufacturer specifications for Flamemastic 71A, minimum 1/8 inch wet thickness. Localized deviations in the coating and/or defects would not impact the results of the analysis.

NRC Question 4:

What controls are in place to maintain an acceptable cable loading in the future?

FPL Response:

Appropriate changes will be made to the Unit 1 UFSAR to include the bases for the pending NRC SER associated with this exemption request resubmittal. The UFSAR change will include sufficient detail to ensure that future modifications do not inadvertently affect the SER bases.

A limit of 3.1 kg per meter of cable tray length has been calculated for the addition of new combustible cable jacket and insulation material to the worst case locations evaluated in the report. This limit is based on a factor of safety of 2 with respect to critical radiant heat flux. This limit of 3.1 kg/m is for IEEE 383 qualified cables with a heat release rate less than 400 kW/m^2.

NRC Question 5:

Are the following assumptions valid;

NRC Question 5 (Part 1):

- the exemption only pertains to cable trays in containment structure and the interior biological shield between radial column lines 2 and 6;

FPL Response:

Yes. See the response to Question 1 of the NRC RAI dated August 31, 2001 as submitted in FPL's letter L-2001-267, dated November 29, 2001. The FPL response states, in part, that "The specific scope of this assessment involves the space defined by the containment structure and the interior biological shield between radial lines 2 and 6..."

NRC Question 5 (Part 2):

- redundant cable trays have at least 7 feet (2.1 meters) horizontal separation distance;

FPL Response:

Yes. See Section 3.1 "Cable Raceway Geometry" of the Hughes Report (Page 9).

NRC Question 5 (Part 3):

- cables intersecting redundant cable trays are in conduit and protected;

FPL Response:

Yes. See Section 3.2, "Walkdown Summary," of the Hughes Report (Page 11).

NRC Question 5 (Part 4):

- no intervening or transient combustibles are located near the cable trays;

FPL Response:

Yes. See Section 3.2, "Walkdown Summary," of the Hughes Report (Page 11).

NRC Question 5 (Part 5):

- all electrical cabinets near the cable trays are enclosed with no ventilation openings; and

FPL Response:

Yes. See Section 3.2, "Walkdown Summary," of the Hughes Report (Page 11).

FPL Response to NRC RAI Dated October 4, 2002 (cont.)

NRC Question 5 (Part 6):

- the bottom tray in each stack and the vertical cable trays have noncombustible covers.

FPL Response:

Yes. See the Hughes Report (Page 20), Section 6.1, "Specific Assumptions," regarding horizontal bottom trays:

"The bottom tray is fully enclosed with galvanized steel..."

The vertical trays are addressed in the last paragraph of the Hughes Report (Page 34) Section 8.2.1, which states:

"All three cable trays in the vertical configuration are covered..."

REFERENCES USED IN THIS RESPONSE (also listed in the Hughes Report, Section 15):

Braun, E., Shields, J.R., and Harris, R.H. (1989), "Flammability Characteristics of Electrical Cables Using the Cone Calorimeter," NISTIR 88-4003, National Institute of Standards and Technology, Gaithersburg, MD, January 1989.

Grayson, S.J., Van Hees, P., Vercellotti, U., Breulet, H., and Green, A. (2000), The FIPEC Report, Fire Performance of Electric Cables – new test methods and measurement techniques, Final Report of the European Commission, SMT Programme Sponsored Research Project SMT4-CT96-2059, Interscience Communications Limited, London, 2000.

Lee, B.T. (1985), "Heat Release Rate Characteristics of Some Combustible Fuel sources in Nuclear Power Plants," NBSIR 85-3196, National Institute of Standards and Technology, Gaithersburg, MD, 1985.

Sumitra, P. (1982) "Categorization of Cable Flammability: Intermediate Scale Fire Tests of Cable Tray Installations," NP-1881 Research Project 1165-1, Factory Mutual Research Corporation, Norwood, MA, 1982.